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# REDUCING LOOP EFFECTS IN A WIRELESS LOCAL AREA NETWORK REPEATER

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to PCT Application PCT/US03/16208 entitled REPEATER FOR WLAN, and is further related to and claims priority from U.S. provisional Application Serial No. 60/417,672, filed on October 11, 2002 both of which applications are incorporated herein by reference.

## FIELD OF THE INVENTION

[0002] The present invention relates generally to wireless local area networks (WLANs) and more specifically to reducing the likelihood of frequency contention and erroneous connection loops within a transmission environment with two or more WLAN repeaters.

## BACKGROUND OF THE INVENTION

[0003] Several standard protocols for wireless local area networks, commonly referred to as WLANs, are becoming popular. These include protocols such as 802.11 (as set forth in the 802.11 wireless standards), home RF, and Bluetooth. The standard wireless protocol with the most commercial success to date is the 802.11b protocol although successors such as next generation protocols, such as 802.11g, are also gaining popularity.

[0004] While the specifications of products utilizing the above standard wireless protocols commonly indicate data rates on the order of, for example, 11 MBPS and

ranges on the order of, for example, 100 meters, these performance levels are rarely, if ever, realized. Performance shortcomings between actual and specified performance levels have many causes including attenuation of the radiation paths of RF signals, which are typically in the range of 2.4 GHz in an operating environment such as an indoor environment. Base to receiver ranges are generally less than the coverage range required in a typical home, and may be as little as 10 to 15 meters. Further, in structures having split floor plans, such as ranch style or two story homes, or those constructed of materials capable of attenuating RF signals, areas in which wireless coverage is needed may be physically separated by distances outside of the range of, for example, an 802.11 protocol based system. Attenuation problems may be exacerbated in the presence of interference in the operating band, such as interference from other 2.4GHz devices or wideband interference with in-band energy. Still further, data rates of devices operating using the above standard wireless protocols are dependent on signal strength. As distances in the area of coverage increase, wireless system performance typically decreases. Lastly, the structure of the protocols themselves may affect the operational range.

[0005] Repeaters are commonly used in the mobile wireless industry to increase the range of wireless systems. However, problems and complications arise in that system receivers and transmitters may operate at the same frequency in a WLAN utilizing, for example, 802.11 or 802.16 WLAN wireless protocol. In such systems, when multiple transmitters operate simultaneously, as would be the case in repeater operation, difficulties arise. Typical WLAN protocols provide no defined receive and transmit periods and, thus, because random packets from each wireless network node are spontaneously generated and transmitted and are not temporally predictable,

packet collisions may occur. Some remedies exist to address such difficulties, such as, for example, collision avoidance and random back-off protocols, which are used to avoid two or more nodes transmitting packets at the same time. Under 802.11 standard protocol, for example, a distributed coordination function (DCF) may be used for collision avoidance.

[0006] Such operation is significantly different than the operation of many other cellular repeater systems, such as those systems based on IS-136, IS-95 or IS-2000 standards, where the receive and transmit bands are separated by a deplexing frequency offset. Frequency division duplexing or multiplexing (FDD or FDM) operation simplifies repeater operation since conflicts associated with repeater operation, such as those arising in situations where the receiver and transmitter channels are on the same frequency, are not present.

[0007] Other cellular mobile systems separate receive and transmit channels by time rather than by frequency and further utilize scheduled times for specific uplink/downlink transmissions. Such operation is commonly referred to as time division duplexing or multiplexing, such as TDD or TDM. Repeaters for these systems are easily built, as the transmission and reception times are well known and are broadcast by a base station. Receivers and transmitters for these systems may be isolated by any number of means including physical separation, antenna patterns, or polarization isolation.

[0008] Thus, WLAN repeaters operating on the same frequencies without TDD or TDM capability have unique constraints due to the above spontaneous transmission

capabilities and therefore require a unique solution. Since these repeaters use the same frequency for receive and transmit channels, some form of isolation must exist between the receive and transmit channels of the repeater. While some related systems such as, for example, CDMA systems used in wireless telephony, achieve channel isolation using sophisticated techniques such as directional antennas, physical separation of the receive and transmit antennas, or the like, such techniques are not practical for WLAN repeaters in many operating environments such as in the home where complicated hardware or lengthy cabling is not desirable or may be too costly.

[0009] One system, described in International Application No. PCT/US03/16208 and commonly owned by the assignee of the present application, resolves many of the above identified problems by providing a repeater which isolates receive and transmit channels using a frequency detection and translation method. The WLAN repeater described therein allows two WLAN units to communicate by translating packets associated with one device at a first frequency channel to a second frequency channel used by a second device. The direction associated with the translation or conversion, such as from the frequency associated with the first channel to the frequency associated with the second channel, or from the second channel to the first channel, depends upon a real time configuration of the repeater and the WLAN environment. The WLAN repeater may be configured to monitor both channels for transmissions and, when a transmission is detected, translate the received signal at the first frequency to the other channel, where it is transmitted at the second frequency.

[0010] The above described approach solves both the isolation issue and the spontaneous transmission problems as described above by monitoring and translating

in response to packet transmissions and may further be implemented in a small inexpensive unit. The base concept of the above described approach is generally suited to scenarios where a single repeater is used for example between an Access Point (AP) and a mobile communication unit or station.

[0011] However, in multiple repeater environments where, for example, two or more repeaters are used within the same WLAN environment, undesirable interaction such as jamming or feedback may occur between two repeaters. Potential causes include operating two or more repeaters on the same frequencies where the repeaters are providing repeater servicing for clients from the same AP. Such a conflict may exist, for example, where a client device/station (STA) can only be heard by a single repeater transmitting on a first frequency (F1), and the repeater transmits to the AP on a second frequency (F2). Another repeater may also transmit on F1 thus interfering with station transmissions also at F1.

[0012] A second example of undesirable interaction may occur when repeaters are chained together in a straight line order, such as AP-R1-R2-STA. In such an exemplary scenario, an AP may transmit, for example, on F1, repeater R1 transmits on F2, and repeater R2 will transmit on F1 again to STA. Problems may arise due to feedback or jamming caused by transmission loop-back arising from a node, for example, an AP or STA, hidden or lower in receive power than the signal from an adjacent repeater, while repeaters R1 and R2 operate on the same pair of channels. Thus for example, if R2 receives a signal transmitted by R1, and re-transmits on the same frequency used by R1 to receive causing either a reduction in signal quality or a

constructive feedback situation where each repeater progressively amplifies the signal ultimately resulting in an oscillation.

## SUMMARY OF THE INVENTION

[0013] Thus a method and apparatus for handling the above described problems in a wireless local area network (WLAN) are described, wherein in accordance with one exemplary embodiment, the WLAN includes a base unit connected to a wide area network. The base unit communicates with at least one client unit using a protocol requiring the base unit and the at least one client unit to receive and transmit information on a same frequency channel chosen from at least two available frequency channels, such as in accordance with an 802.11, or the like protocol. The base unit preferably identifies which of multiple operating frequencies is chosen in a control parameter transmitted in a protocol message associated with the protocol.

[0014] In accordance with various exemplary embodiments, the present invention includes a series of techniques for solving or at least reducing problems associated with WLAN interference previously described herein above. Such techniques preferably include for example, passive monitoring, rule based channel selection, active monitoring, and feedback detection and suppression via gain control. It will be appreciated that the techniques described herein may be used individually or together without departing from the scope of the invention. Moreover, in accordance with various preferred exemplary embodiments, the above described techniques may be prioritized such that, for example, passive monitoring is first performed, then rule based channel selection, then active monitoring, and then gain control, or another suitable order of priority.

[0015] Thus, to avoid the repeater interactions described above, it is desirable to configure each repeater within range of another repeater on different repeating channels. To best accomplish such configuration and reconfiguration, for example, in accordance with an exemplary passive monitoring approach, active channels are preferably monitored and configured such that only one of a contending WLAN frequency channel, such as a single channel used or re-used by different repeaters or other WLAN nodes within range of each other, has activity on it. Accordingly, no two repeaters within the passive monitoring area are likely to be configured to use the same channel or set of channels. Further, exemplary passive monitoring processes may be made more efficient by defining rules for scanning and selecting channels to monitor based on any number of diverse criteria, heuristics or the like, ensuring a high degree of probability that channel pairs will be sufficiently isolated to prevent degradation in transmission quality based on various metrics associated with the repeaters, communication units or stations, APs and other network nodes, elements, and the like as would be appreciated by one of ordinary skill in the art.

[0016] In accordance with another exemplary embodiment, an active monitoring approach may be used as safeguard against repeater or node interaction. In active monitoring, after channels have been "pre-selected", an exemplary repeater may transmit a signal, such as a test signal, on a repeater channel where no apparent activity is present. The AP channel or other channel of interest, such as a proximate channel where there would be a likelihood of a false connection loop, would then be monitored for activity corresponding to the transmission to determine whether returned transmissions are present from, for example, a false connection loop, which

may be likely to cause system level issues. An exemplary repeater in accordance with an active monitoring approach preferably continues to monitor the AP channel and the repeater channel for a clear channel assessment and a determination that WLAN rules are being complied with prior to transmission on the repeated channel to prevent any collision of signals on the AP channel, repeater channel, channel of interest or the like. It should be noted that the signal generated by the repeater to accomplish exemplary active monitoring methods may be any signal compliant with part 15.247 or part 15.407 of F.C.C. rules, or the rules of the WLAN system the repeater is operating within, including, for example, a spread spectrum or frequency hopped signal, and may even include pulses, impulses, wide band signals, or the like including generic broad band or band limited noise. It will be appreciated that one benefit of using such signals may include being better able to characterize the WLAN communication environment and the interference potential of adjacent nodes within the repeater environment described in connection with the present invention.

[0017] In accordance with yet another exemplary embodiment, feedback detection and suppression are used with attendant advantages in situations where no unused or empty channels are available, and where other repeaters may be active on the paired channels. Such a scenario is likely, for example, in an 802.11b protocol environment operating in the 2.4 GHz band where only 3 channels are available. Typically, channels 1 and 3 are always reserved due to protocol implementation and related concerns. Thus, feedback or oscillation detection is preferably performed for other channels in one or more of the following ways: changing the transmit gain on a channel and determining whether transmit power is correspondingly modified, examining timing parameters of the signal waveform on a channel, or by detecting a

maximum power output beyond a set value, or the like. The detected feedback condition may be suppressed by reducing, for example, the transmit gain significantly to where the transmit power does drop. Stability may be ensured by removing a portion of additional gain margin at the point where transmit power drops.

[0018] It should be noted that the effect of repeating feedback on signal integrity is minimal. With delay in the repeater on the order of less than 1 microsecond (μs), there will be an exponentially decaying multi-path effect generally as follows: first path 0dB, second path –10 dB, third path –20 dB, and so on. The delays associated with typical decay are sufficiently small such that a significant portion of signal energy remains within the range of the equalizer in the receiver or within the parameters of, for example, 802.11a protocol, and thus will not cause significant performance degradation.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a block diagram illustrating a wireless network environment including two exemplary repeaters.

[0020] FIG. 2 is a connection diagram illustrating potential connections which may be established between exemplary repeaters, an AP and mobile communication station in a WLAN.

[0021] FIG. 3 is a connection diagram illustrating additional potential connections which may be established between exemplary repeaters, an AP and mobile communication station in a WLAN.

[0022] FIG. 4 is a flow chart illustrating exemplary steps associated with techniques such as passive monitoring in accordance with various exemplary embodiments.

[0023] FIG. 5 s a flow chart illustrating exemplary steps associated with techniques such as active monitoring in accordance with various exemplary embodiments.

## DETAILED DESCRIPTION OF THE INVENTION

[0024] Referring now to FIG. 1, a wide area connection 101, which could be, for example, an Ethernet connection, a T1 line, a wideband wireless connection or any other electrical connection providing a data communications path, may be connected to a wireless gateway, or access point (AP) 100. The wireless gateway 100 sends RF signals, such as IEEE 802.11 packets or signals based upon Bluetooth, Hyperlan, or other wireless communication protocols, to client units 104, 105, which may be personal computers, personal digital assistants, or any other devices capable of communicating with other like devices through one of the above mentioned wireless protocols. Respective propagation, or RF, paths to each of the client units 104, 105 are shown as 102, 103.

[0025] While the signal carried over RF path 102 is of sufficient strength to maintain high-speed data packet communications between the client unit 104 and the wireless gateway 100, the signals carried over the RF path 103 and intended for the client unit 105 would be attenuated when passing through a structural barrier such as walls 106 or 107 to a point where few, if any, data packets are received in either

direction if not for wireless repeaters 200, 204 the structure and operation of which will now be described.

[0026] To enhance the coverage and/or communication data rate to the client unit 105, wireless repeaters 200, 204 receive packets transmitted on a first frequency channel 201 from the wireless gateway 100. The wireless repeater 200, which may be housed in an enclosure typically having dimensions of, for example, 2.5"x3.5"x.5", and which preferably is capable of being plugged into a standard electrical outlet and operating on 110 V AC power, detects the presence of a packet on the first frequency channel 201, receives the packet and re-transmits the packet with more power on a second frequency channel 202. Unlike conventional WLAN operating protocols, the client unit 105 operates on the second frequency channel, even though the wireless gateway 100 operates on the first frequency channel. To perform the return packet operation, the wireless repeater 200 detects the presence of a transmitted packet on the second frequency channel 202 from the client unit 105, receives the packet on the second frequency channel 202, and re-transmits the packet on the first frequency channel 201. The wireless gateway 100 then receives the packet on the first frequency channel 201. In this way, the wireless repeater 200 is capable of simultaneously receiving and transmitting signals as well as extending the coverage and performance of the wireless gateway 100 to the client unit 105.

[0027] It should also be appreciated that wireless repeater 200 may be used to enhance communications in a peer-to-peer network from one client unit to another client unit. In a scenario where many units are isolated from one another, wireless repeater 200 preferably acts as a wireless hub allowing two different groups of units

to communicate in such an isolated environment where communication in accordance with standard RF propagation and coverage rules would otherwise be inhibited.

[0028] However, as described herein above, repeater systems using frequency translation may encounter problems, for example, when beacon signals are used. In accordance therefore with the present invention, range extension may be realized in such systems using repeaters for wireless local area networks and may be particularly advantageous when specific protocols are used, such as, for example, the 802.11 series of protocols by modifying the beacon signal to reflect the frequency translation. As noted however problems arise when adjacent nodes using or re-using translated frequencies within range of each other may establish false connections which lead to problems from node to node in terms of data traffic integrity. False connections may also lead to repeater to repeater oscillations when both repeaters are using the same frequency pairs and may further lead to system problems causing a general failure in the WLAN environment.

[0029] Referring again to FIG. 1, as described herein above, wide area connection 101 is preferably connected to a wireless gateway or access point (AP) 100. AP 100 communicates by transmitting and receiving, for example, data packets to wide area connection 101 on one side and sends RF signals 102 and 103, to client units 104 and 105. In accordance with a preferred embodiment, RF signals 102 and 103 preferably carry, for example, IEEE 802.11 packets. In accordance with alternative exemplary embodiments, RF signals 102 and 103 could also be associated with Bluetooth, Hyperlan, 802.16, 802.20, TDS-CDMA, or the like wireless communication protocols. Two propagation paths to each of the client units are further shown

associated with RF signals 102 and 103. It should be noted that while the signal strength resulting from the path associated with RF signal 102 is sufficient to maintain high speed data packet communications with client unit 104, the signal strength resulting from the path associated with RF signal 103 however is attenuated, such as from obstacle 106 which may be a wall or other obstruction, to a level where few or no data packets are able to be received in either direction between, for example, AP 100 and client unit 105.

[0030] To address the difficulties posed by obstructions as described above and attendant attenuation of the signal strength along obstructed paths and thus to enhance the coverage and/or communication data rate to client unit 105, exemplary wireless repeater 200, as shown in FIG. 1, may be used to retransmit packets beyond a range limited by propagation path constraints through, for example, frequency translation. Packets transmitted on a first frequency channel 201 from AP 100 are received at repeater 200 and re-transmitted, preferably with a greater power level, on a second frequency channel 202. Client unit 105 preferably operates on second frequency channel 202 as if AP 100 were also operating on it, such as with no knowledge that AP 100 is really operating on first frequency channel 201 such that the frequency translation is transparent. To perform return packet operations, repeater unit 200 detects the presence of a transmitted return packet on second frequency channel 202 from client unit 105, and is preferably configured to receive the packet on second frequency channel 202, and to retransmit the data packet to, for example AP 100, on first frequency channel 201.

[0031] Repeater 200 may thus receive and transmit packets at the same time on different frequency channels thereby extending the coverage and performance of the connection between AP 100 and client unit 105, and between peer-to-peer connections such as from one client unit to another client unit. When many units are isolated from one another, repeater unit 200 further acts as a wireless bridge allowing two different groups of units to communicate where optimum RF propagation and coverage or, in many cases, any RF propagation and coverage was not previously possible.

[0032] Wireless repeater 200 is preferably capable of receiving two different frequencies simultaneously, such as first frequency channel 201 and second frequency channel 202 determining which channel is carrying a signal associated with, for example, the transmission of a packet, translating from the original frequency channel to an alternative frequency channel and retransmitting the frequency translated version of the received signal on the alternative channel. Details of internal repeater operation may be found in co-pending PCT Application No. PCT/US03/16208.

[0033] Referring still to FIG. 1, and in accordance with one preferred exemplary embodiment of an 802.11 system, a beacon message transmitted from AP 100 to another device has a specific field, such as the channel number field of a direct sequence (DS) parameter set. However the channel number identified in the beacon transmitted from AP 100, for example, to repeater 200, does not correspond to the actual channel number used between AP 100 and repeater 200, such as channel 201.

[0034] Rather, in accordance with various exemplary and preferred exemplary embodiments, the channel of operation identified in the beacon from AP 100 is the channel to be used after frequency translation occurs in repeater 200, which will be referred to hereinafter as frequency translating repeater 200. Repeater 200 may further be capable of receiving a beacon from AP 100, modifying the contents of the beacon with the correct channel number in the DS parameter set segment of the beacon and retransmitting the modified beacon. It should be noted that such operation allows use of 802.11 protocols with no modifications to APs, client devices, or other nodes since the "spoofed" parameter is handled by nodes in a normal fashion. The original beacon transmitted from AP 100 containing the incorrect channel number will be ignored by client devices after being directed to the new translated channel number contained in the beacon having the spoofed DS parameter. It should be apparent to one of ordinary skill in the art how to transmit the signals on the frequencies described herein according to the protocols set forth, and, further, the DS parameter may be reset easily by modifying its channel set value, in accordance with for example, IEEE 802.11, Paragraph 7.3.2.4 "DS Parameter Set Element".

[0035] Thus frequency translating repeater 200 converts the 802.11b modulated packet from a first frequency channel to a second frequency channel, where it may be received by one or more clients, such as station devices (STA) or client units 104 or 105. Client units 104 or 105 preferably receive a beacon identifying an 802.11b channel as being the appropriate channel for communication, and would receive information packets translated by the repeater 200 from a first channel to a second channel. It will be appreciated by one of ordinary skill in the art that an exemplary frequency translating repeater in accordance with various exemplary and alternative

exemplary embodiments may translate between any 2 channels, such as from an 802.11a channel to another 802.11a channel, 802.11a channel to an 802.11b channel, 802.11b channel to an 802.11a channel, 802.11b channel to another 802.11b channel, and so on. It is further contemplated that an 802.11g channel or a channel associated with any suitable wireless protocol may also be used in accordance with frequency translation, without departing from the invention.

[0036] On the return signal path, station client unit 105 may transmit the standard compliant 802.11b signal in the appropriate frequency band, such as defined in the standard, and repeater 200 detects the 802.11b signal and translates packets carried thereon to frequency channels defined in the 802.11a standard, but not conforming to the 802.11a OFDM modulation. AP 100 may receive the 802.11b modulated waveform in the frequency channels defined for 802.11a signals, and will process the waveform it as if it were in a 802.11b frequency channel.

[0037] It will be appreciated that in order to perform frequency translation to channels in different bands, a multi-band capability is preferably present in one or more of an exemplary AP, frequency translating repeater, client station or the like node of an exemplary WLAN. Such a multi-band capability preferably allows, for example, both 2.4GHz and 5GHz waveforms to be generated and transmitted and detected and received through the use of appropriate hardware such as antennae, power control circuits, transceivers, and control software within the same device or node.

[0038] In accordance with various exemplary and alternative exemplary embodiments, AP 100 may use an IEEE 802.11b or IEEE 802.11g modulation compliant waveform, but transmits signals on a non standard-conforming band, such as on a different band from one defined as appropriate by the IEEE 802.11a standard. A frequency translating repeater 200, 204 may thus converts an exemplary IEEE 802.11b or IEEE 802.11g modulated packet from the "a" band on one channel to the "b" band on another channel where it is utilized by a station device such as client unit 105. When signals return from a station, such as client unit 104 or 105 to AP 100, client units 104 or 105 may preferably transmit the standard 802.11b compliant signal in the appropriate band, such as defined in the standard, repeater 200 detects the 802.11b signal and translates it in accordance with frequency channels defined in the 802.11a standard, but in conflict with, for example, the channel of operation, if present, in the DS parameter set message.

[0039] It should be noted that in accordance with various exemplary and alternative exemplary embodiments, for example as illustrated in FIG. 1, a "Backhaul" channel may refer to the channel with the incorrect DS Parameter set message and a translating repeater may be referred to as "off-ramp" repeater 204. FIG. 1 further shows "hi-way" repeater 200 and "off-ramp" repeater 204 with three distinct channels of operation: channel 201 between AP 100 and hi-way repeater 200, interim channel or "off-ramp" channel 202 between hi-way repeater 200 and off-ramp repeater 204, and local channel 203 between off-ramp repeater 204 and client unit 105.

[0040] It should be noted that one or more repeaters such as hi-way repeater 200 and off-ramp repeater 204 may connect to any specific backhaul or off-ramp channel allowing an increase in coverage for any given AP 100, as communication with stations (STA), client units, or the like could be extended to the radiated foot print potentially including a plurality of repeaters rather than just a single repeater. It is further important to note that hi-way repeater 200 and off-ramp repeater 204 simply translate and rebroadcast information packets as well as beacon information thereby making them similar to repeaters described in co-pending PCT Application No. PCT/US03/16208.

[0041] Before describing the operation of an exemplary embodiment in accordance with FIG. 1, it must be understood that the present invention may be used in an environment where present wireless local area standards are used. As defined, for example, in the 1999 IEEE 802.11 wireless standards and as further shown in Table 1 herein below, paragraphs 15.4.6.2 and 18.4.6.2, all the channels defined for transmission with the DS parameter are in the 2.4 GHz band.

| CHNL-ID | Freq | X'10' FCC | X'20' IC | X'30' ETSI | X'31' Spain | X'32' France | X'40' MKK |
|---|---|---|---|---|---|---|---|
| 1 | 2412MHz | X | X | X | | | |
| 2 | 2417MHz | X | X | X | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | 2422MHz | X | X | X | | | |
| 4 | 2427MHz | X | X | X | | | |
| 5 | 2432MHz | X | X | X | | | |
| 6 | 2437MHz | X | X | X | | | |
| 7 | 2442MHz | X | X | X | | | |
| 8 | 2447MHz | X | X | X | | | |
| 9 | 2452MHz | X | X | X | | | |
| 10 | 2457MHz | X | X | X | X | X | |
| 11 | 2462MHz | X | X | X | X | X | |
| 12 | 2467MHz | | | X | | X | |
| 13 | 2472MHz | | | X | | X | |
| 14 | 2477MHz | | | | | | X |

Table 1

[0042] As will be appreciated from the above description, repeaters operate to detect signals on one of two channels and retransmit the signals on the other channel as described in detail in co-pending PCT Application No. PCT/US03/16208.

[0043] A problematic repeater condition may arise however, in exemplary scenario 300, as illustrated FIG. 2, wherein two repeaters R1 320 and R2 330 are configured to service one AP 310 which is within the transmit range of both repeaters via, for example, wireless connections 301 and 303. Repeaters R1 320 and R2 330 may further be capable of listening to each other's respective transmissions via a connection established over, for example, link 302. In exemplary scenario 300, the

only connection established to communication unit or station device or STA 340 is connection 304 which as will be appreciated is a wireless or RF link. Problems arise when repeaters R1 320 and R2 330 are operating on the same pair of channels, such as AP and repeater channels. When AP 310 transmits, both R1 320 and R2 330 detect the transmission on, for example, a first frequency F1 and retransmit on a second frequency F2, such as the repeater channel. In some locations within the WLAN environment, there will appear to be a 700ns multi-path signal which is easily compensated for by an 802.11a equalizer for example. The primary problems arise when an isolated client station STA 340 transmits on F2 which, as describe above, is the repeater channel. R2 330 then repeats the transmission on F1 to AP 310. R1 320 detects the transmissions from R2 330 on F1 and tries to retransmit the detected transmissions. If R1 320 happens to select F2 as the transmit frequency, a loop will be established between R1 320 and R2 330. With sufficient gain, the RF loop may oscillate, via, for example, positive feedback causing any signals destined to STA 340 over connection 304 to be jammed.

[0044] FIG. 3 illustrates another exemplary scenario 400 commonly referred to as a hidden node repeater scenario. In accordance therewith, R2 430 is connected to AP 410 via R1 420. Client station STA 440 may preferably connect to either R1 420 or R2 430 based on connection quality or the like. Assuming connection 403 to R2 430 is better, one undesirable situation can occur when connection 403 is made but is silent, such as no traffic is being generated. When R1 420 turns on it will not be able to detect the presence of R2 430 and thus cannot avoid channels associated with R2 430. A second more serious situation may occur when client station STA 440 transmits, and R2 430 repeats the transmitted signal to R1 420, which then transmits

the signal to AP 410 on F1. It should be noted that in accordance with this scenario, the signal transmitted from client station STA 440 may also be detected on F1, capturing R1 420 and preventing it from repeating the signal from R2 430 back to AP 410.

[0045] Thus, in accordance with the present invention, techniques will be described to deal with the above described exemplary scenarios, including for example, preferred techniques also described above. In accordance with various exemplary embodiments, the present invention will prevent or significantly reduce the undesirable effects associated with the above described situations. Referring now to FIG. 4, a flow chart is shown illustrating various states which are preferably associated with for example, an exemplary state machine for initial channel selection in an exemplary passive approach further described herein below.

[0046] The feedback problems described above may be avoided or significantly reduced by careful selection of initial channels. In FIG. 4, channels are preferably incrementally, or otherwise, scanned until the scan is complete at 502. Each time a channel is to be monitored an exemplary receiver may be tuned to a new channel and may be monitored for the presence of a signal or like activity at 503. If signal activity is present at 504 an attempt may be made to qualify the activity as acting like an AP, another WLAN node, or like some undesirable signal, such as, for example, a radar or microwave oven. At 505, if no activity is present, the next channel is scanned and so on. If activity is detected, a determination may be made that the transmission possesses properties indicating WLAN transmissions at 505. Properties indicating WLAN transmissions may include but are not limited to: detection of a known power

level, or a known sequence of modulated symbols; a nearly periodic transmission indicating beacon messages from an AP; a known sequence possibly encompassing entire beacon message intervals, a level of activity on the channel indicative of WLAN transmissions, and the like. The characteristics of the transmissions may further be qualified against known system parameters associated with WLAN packets such as minimum and maximum packet durations.

[0047] When activity is detected, it may be qualified, as described above, as AP or some other type of signal such as for example, an interference signal. If other, such as if the signal is deemed to be interference, its characteristics may be stored at 507 in a data storage device such as table 2 for later use, and if the signal is deemed to be associated with an AP it is stored at 506 in table 1 for later use. In accordance with various preferred exemplary embodiments, after table 1 and table 2 are completed, at 506 and 507 indicating that channel scanning is complete, the best AP channels are preferably selected in 508. If valid AP channels are found at 509, channels may be pre-selected at 511 using, for example, rules to be described in greater detail herein below.

[0048] Choosing or "pre-selecting" a repeater channel in accordance with preferred exemplary embodiments prevents two repeaters from operating on the same pair of channels. Moreover, by defining "known" or preferred channel spacing and by defining and applying usage rules, depending on which channel or channels are available for re-transmission, and which are active with transmissions that qualify as AP transmissions, channel infringement may further be avoided. It should be noted that usage rules in accordance with various exemplary embodiments may include for

example, rule set A) always incrementing by two or another predefined defined number of channels from the AP channel, unless no valid channels exist, decrementing 3 channels or another predefined number of channels, if no valid channels exist; rule set B) defining a one to one valid channel mapping based on a table, mathematical equation, or other suitable method wherein every valid AP-like channel is assigned or otherwise associated with valid repeater channels and where the defined repeater channels and AP-like channel would not overlap with a repeater who is sending an AP-like signal.

[0049] One of ordinary skill in the art will recognize that the above rules are presented for exemplary purposes. Other rules may be devised for reducing or eliminating channel interference based on parameters as described herein above, or other parameters relevant to channel selection as would be appreciated by one of ordinary skill in the art. Also, one of ordinary skill will recognize that not all channels must necessarily be scanned. Rather, an exemplary WLAN in accordance with the present invention channels may be scanned and, upon finding one or more available channels, the best AP channel may be selected at 508. Table 1 at 506 and table 2 at 507 may further be used to determine the best pre-selected repeater channels.

[0050] For example, based on exemplary channel pre-selection steps as described above, at a minimum, pre-selected repeater channel or channels in Table 1 at 506 may be monitored for activity, indicating that they are either already in use by another AP or another device, or have already been selected for use as a repeater channel by another repeater or repeaters. It should be noted that the pre-selected repeater channel

or channels may be disqualified if AP-like signals are detected, and the next repeater channel selected for monitoring for categorization in table 2 at 507 or table 2 at 506. It should further be noted that a conclusive determination of whether an actual AP is generating AP-like signals is not necessary. It is sufficient to determine that the signals resemble those of an AP to disqualify a channel.

[0051] Alternatively, pre-selected repeater channels could be disqualified in 509 based on monitoring both the AP-like and the pre-qualified repeater channels simultaneously and comparing activity parameters on the two channels to determine if the similarities are such that the transmissions on the pre-selected repeater channel is a transmission from a repeater using the same AP-like channel and the same repeater channel as being monitored. If a sufficient level of inactivity is detected on a pre-selected repeater channel, that channel may be qualified as passing the passive tests for valid use as a repeater channel, for example, in 511.

[0052] Referring now to FIG. 5, a flow chart is shown illustrating various exemplary techniques which might be associated with for example, an exemplary state machine for initial channel selection in an exemplary active approach. It should be recognized that active channel selection may preferably be performed after passive selection of the AP channel and pre-selection of the repeater channel, as an additional step to further mitigate against the effects of feedback. Alternatively, a channel could be pre-selected based on other factors, or could be randomly selected for active testing. In accordance with various preferred exemplary embodiments, a pre-selected repeater channel may be paired with a detected AP channel, and information identifying the pre-selected repeater channel stored in a storage device or the like as in

602. An exemplary repeater may then perform a distributed coordination function procedure, or the like, for example, as defined in the IEEE 802.11 MAC specification in 603 - to prevent jamming other users.

[0053] When it is determined that transmission is valid, a test signal may be sent on the pre-selected repeater channel at 604. It will be appreciated that the test signal may be a frequency hopped signal, a spread spectrum signal, an OFDM signal, or may be, for example, wide band or band limited noise, such as white noise or the like. While performing the test transmission on a pre-selected repeater channel, the AP channel or AP-like channel, may be monitored, for example, at 605 to detect the presence of another repeater operating on the same two channels as the testing repeater, such as the detected AP-like channel and the pre-selected repeater channel, as defined, for example, by the testing repeater.

[0054] If a transmission is detected on the AP-link channel with the same signal parameters at 605, the AP-like signal may be defined to be a repeater signal operating on the same two channels. It should be noted that a match of the paired signals may preferably be determined based on signal parameters which may include duration, amplitude or power modulations, on/off packet times, and inter transmission intervals in situations wherein more than one transmission is sent, or the like. The matched pair of frequencies are preferably stored in a table which may be referred to as, for example, a "known repeater table" at 607. A test may be performed at 609 to determine whether other repeater channels are available, and, if so, the pre-selected repeater channel may be disqualified as valid for use, and another channel selected as a pre-selected repeater channel at 611 whereupon an exemplary process may return,

for example, to 603. It should be noted that the above test transmission process, may further be performed on different channels, as derived from the AP and interference tables at 608 until no correlated or matching transmissions are detected on the AP-like paired channel. It should be noted that if no repeater activity is detected at 605 the pre-selected repeater channel is defined as valid for use as a repeater channel, and the repeater may be enabled for normal operation.

[0055] If no new repeater channels are available at 609, two actions are preferably possible: either an exemplary WLAN, or associated device or system can stop operation and declare no valid repeater channels available for operation, whereupon another AP channel may be tried, or, alternatively, gain associated with the transmitted signal may be reduced to prevent oscillation or feedback at 610. The reduced gain value may be archived by actively controlling or biasing, for example, an AGC loop in an exemplary repeater. The gain is preferably reduced until a determination is made that the possibility of RF oscillation or positive feedback is occurring is substantially reduced or eliminated. It is generally the case that if the gain is reduced and no reduction in transmit power occurs, oscillation or feedback reduction has been accomplished.

[0056] Gain may also be reduced until a linear relationship develops between transmit power and gain, such as until transmit power begins to reduce in a linear fashion with the reduction in gain level. When a state is attained where the linear relationship described above develops, it can be assumed that no oscillation is occurring. The existence of such a state may be determined by other techniques as will be apparent to those of ordinary skill in the art. It should also be noted that the

reduced power state is advantageous as it allows operation to be maintained, even if under sub-optimal conditions. Further, in accordance with various exemplary and alternative exemplary embodiments, when a reduced power state is entered, an indication may be provided to the user to allow the repeater to be moved to a better location.

[0057] One of ordinary skill in the art will recognize that the above described devices such as, APs, repeaters, client devices or stations, base units or stations, and the like in accordance with various exemplary and alternative exemplary embodiments, take many forms in a wireless communication network or WLAN. For example, an exemplary AP may correspond to a base unit such as for example, an 802.11 AP connected to a wired or wireless wide area network infrastructure, including but not limited to: a Digital Subscriber Line (DSL), cable modem, PSTN, Cat5 Ethernet cable, cellular modem, or other wireless local loop type system for example in accordance with 802.16, or the like. Moreover, an exemplary WLAN or wireless network in accordance with various exemplary embodiments, may be in accordance with many different protocols, including but not limited to: 802.11, 802.11b, 802.11a, 802.11g, 8-2.16, 802.20, 802.15.3.a, and additional extensions of the 802.11 WLAN protocol, Bluetooth, TDS-CDMA, TDD-W-CDMA, or the like.

[0058] Further, while various exemplary embodiments of the present invention are described herein in the context of existing standards, such as 802.11a and 802.11b, and those additional standards and environments as described above, techniques may be practiced in an environment with different standards or different configurations without departing from the present invention. Thus, the invention is described herein

in detail with particular reference to presently preferred embodiments. However, it will be understood that variations and modifications can be effected within the scope and spirit of the invention.